PCT/AU00/00830

10/030952

REC'D 28 JUL 2000

WIPO PCT

Patent Office
Canberra

4

I, LEANNE MYNOTT, ACTING MANAGER PATENT ADMINISTRATION hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 2828 for a patent by MEAT & LIVESTOCK AUSTRALIA LIMITED filed on 14 September 1999.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

WITNESS my hand this
Twenty-first day of July 2000

LEANNE MYNOTT
ACTING MANAGER PATENT ADMINISTRATION

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

AUSTRALIA

Patents Act 1990

ORIGINAL

PROVISIONAL SPECIFICATION

Title: IMAGE DATA ANALYSIS

Applicant: MEAT & LIVESTOCK AUSTRALIA LIMITED

The invention is described in the following statement:

IMAGE DATA ANALYSIS

This invention relates to image data analysis for objects such as meat carcases and meat cuts although the invention may also be applicable to other agricultural, mineral or manufactured objects.

In the meat industry, specialist trained and skilled operators are employed, in abattoirs for example, in order to inspect each animal carcase and to provide estimates or gradings of various parameters, such as the predicted saleable meat yield of each carcase, Such predictions of meat yield and gradings are very important for fixing a fair value for the carcase and for determining uses to which the carcase and meat cuts will be destined. Obviously it is very important for the meat industry generally including producers, processors and consumers that such operators are consistent both within a particular abattoir or processing facility and between different facilities at different place and different times.

There have been proposed and developed automated systems for image capture and colour analysis for automating yield predictions or gradings, or at least for providing some objective replacement or supplement to human operators. For predicting the meat yield of a carcase, yield equations have been developed by statistical methodologies such as multiple regression analysis, such yield equations using the colour data to provide estimates of meat yield. However, the results of such automated analysis and yield predictions have not been of acceptable reliability or at least have been capable of significant improvement.

It is an object of the present invention to provide a method of analysing colour image data relating to a target object to derive or predict more accurately and consistently a property of the object of which the colour is an indicator.

In the past, in order to predict the yield of meat carcase, i.e. the amount of saleable meat in the carcase, colour data captured by a colour video camera has been utilised in the form of R, G, and B values (red, green and blue values) in yield equations derived from

multiple field runs as described above. Particular care ought to be taken to ensure as far as possible that the R, G and B colour values are reliably and consistently measured both between different sites with different ambient conditions and using different cameras, and also throughout different periods of use, e.g. throughout a day, when lighting conditions can change. Our earlier patent application No. PCT/AU98/00135 (publication No. WO98/39627) provides considerable detail concerning calibration procedures and systems for achieving the reliable and consistent colour measurements.

However we have found that even accurate and repeatable measurements in the form of R, G and B values when utilised in the relevant yield equations can provide predicted yields which are still susceptible of significantly improved accuracy or consistency.

According to the present invention there is provided a method of analysing colour image data relating to a target object to derive or predict a property of the object of which colour is an indicator, the method including the step of processing the colour data to derive light intensity independent measures of colour values, followed by the step of calculating the property of the object utilising the light intensity independent colour measures in a predictive equation.

Generally, in the field of meat quality grading, the light intensity independent measures of colour values are used in equations developed to predict a quantitative meat or carcase quality measure, e.g. "yield" in Australia, "conformation" or "fat score" in the EUROP grading system, or "yield grade" or "quality grade" in the USDA grading system.

For example, in the particular field of meat carcase yield prediction, the method includes the step of processing the colour data for a carcase to derive light intensity independent measures of colour values for the carcase, followed by the step of calculating the

meat yield of the carcase utilising the light intensity independent colour measures in a yield predictive equation.

It will be convenient to further describe the invention in relation to the particular field for which the invention has been developed, namely beef carcase yield prediction and grading, however it is to be understood that the principles, methods and systems can be adapted to other field of use.

Intensity Normalised Colour Space

Considerable development of our beef carcase system ("BCS") for colour data capture and analysis has been towards achieving acceptable site-to-site consistency. We established that the existing methods of lighting distribution compensation on a plane did not adequately remove lighting variations in RGB space. To combat these variations, the present invention was developed involving use of an intensity normalised colour space. That is, the intensity component was removed from the measurements leaving only colour.

Intensity Normalised Components

The intensity normalised class CRiGiI has been adapted from the prior CRGB class consisting of Red, Green and Blue values. The class consists of the member variables Ri; Gi; and I; where Ri is the intensity normalised red value, Gi is the intensity normalised green value, and I is the intensity. The calculation of these variables is described below. The intensity variable I is only used for reconstruction of the RGB tuple and is not used in any yield equation calculations.

Calculation of RiGiI from RGB

The calculation of the intensity normalised values requires all red, green, and blue measurements of a RGB tuple. In addition, to ensure full intensity independence, a digitiser offset is preferably subtracted (since the offset associated with a digitiser for digitising

measured RGB values in a colour data capture system is obviously not affected by light intensity variation). Through use of an assigned offset value and supply of the RGB values, the intensity normalised values are found as follows:

$$R_i = \frac{(R-k)}{R+G+B-3k}$$

$$G_i = \frac{(G-k)}{R+G+B-3k}$$

$$I = \frac{(R+G+B-3k)}{3}$$

where k is the intensity normalised offset explained above.

Yield Equations

In order to test the use of intensity normalised colour values in predicted yield or other grading measures, some test yield equations were developed from data gathered during a yield trial experiment. During this yield trial experiment, images for many beef carcases were captured at an operating abattoir and various measures obtained from these data were correlated with the saleable meat yield for each of the respective carcases. In this way the yield equations relating measured or calculated parameters of the carcases could be derived by multiple regression analysis (or other statistical analysis techniques) to best fit the data and optimise the fitting or prediction of the actual saleable meat yield.

Two equations derived for the purpose of comparing the performance of a yield prediction equation using intensity normalised variables with a yield prediction equation using intensity based variables are as follows:

$$\text{Yield 1} = 80.2 - 35.4 \times R_{iI} + 19.8 \times B_{iI} \qquad (1)$$

$$\text{Yield 2} = 77.48 - 0.16 \times R_I + 0.054\ G_I + 0.094 \times B_I \qquad (2)$$

where R_{i1} is the intensity normalised red value of a predetermined "area 1" of the carcase where a good predictive correlation between colour values and yield has been empirically determined,

B_{i1} is the intensity normalised blue value of the same "area 1",

R_1 is the intensity based red value for the same "area 1",

G_1 is the intensity based green value for the same "area 1", and

B_1 is the intensity based blue value for the same "area 1".

These two equations were derived using the same data sets so as to provide equivalent equations for comparing predictive ability using one equation with intensity normalised colour values and the other using intensity based colour values.

After testing and evaluation, a further two yield equations were derived from other data gathered at a different yield trial experiment conducted in an operating abattoir which included objective yield data from tissue sampling and laboratory fat analysis. These further equations are:

$$\text{Yield 3} = 72.31 - 0.0059 \times d_1 - 0.14 \times f_1 + 0.015 \times s_1 + 117.62 \times G_{i2} - 23.034 \times R_{i3} - 36.385 \times R_{i4} \quad (3)$$

$$\text{Yield 4} = 124.94 + 0.0039 \times d_2 - 0.42 \times f_2 + 0.026 \times s_1 - 0.26 \times R_1 + 0.13 \times G_1 + 0.077 \times B_3 \quad (4)$$

where d_1 is the distance from the tail to the hind leg bottom, when projected onto a longitudinal line through the carcass,

d_2 is the distance from the brisket to the tail,

f_1 is the ratio w/L, where w is the distance from the point where the hook suspending the beef carcass passes through the hind leg to the point at the end of the profile of the butt, when projected onto the longitudinal line, and

L is the length of the carcass,

f_2 is the ratio x/L, where x is the distance from the hook to the point of the armpit, when projected onto the longitudinal line, and L is the length of the carcass,

s_1 is a measure of the degree of "plumpness" of the shape of the butt, e.g. derived by obtaining a measure of the extent of departure of the butt profile from the line from the point of the tail to the bottom of the hind leg,

G_{i2} is the intensity normalised green value for a predetermined "area 2" of the carcass (different from "area 1") determined to have a predictive correlation to the yield,

R_{i3} is the intensity normalised red value for a different "area 3" of the carcass,

R_{i4} is the intensity normalised red value for a different "area 4" of the carcass, and

B_3 is the intensity based red value for "area 3".

Some of these dimensional parameters are indicated on the accompanying drawing showing a beef carcase in side view as presented to the image capture camera.

It is to be appreciated that these yield equations were derived from particular sets of dimensional and colour data captured during particular yield trials conducted at operating abattoirs, including actual saleable meat yield data obtained using conventional grading techniques for each of the respective carcases. Hence the equations are illustrative only and different equations would result from the statistical analysis techniques used to derive these equations if applied to other sets of test data from carcases. For example only, very different equations would result from dimensional and colour data obtained for different species of beef cattle, different sexes of animals, different age groupings of cattle, different pasture or feeding types and patterns for the cattle (e.g. different types of grasses or pastures, grain fed versus grass fed, different climatic and seasonal conditions, dietary supplements and growth factor or hormone manipulation, etc.), different animal species (cattle, sheep, pigs, goats,

etc), and possibly even mechanical processing variables (such as pelt or hide removal techniques which may affect the extent and location of fat left on the surface of the carcase). Hence these equations are illustrative only of the kind of equations that may be used in implementing the method of the present invention to calculate a property of an object utilising the light intensity independent colour measures in a predictive equation.

Also the numerous variables including dimensional variables, ratios of dimensions, other measures such as the measure of the shape of the butt, as well as the sizes and locations of the predetermined areas of the carcass where colour measurements are taken and used in the predictive equations. These particular exemplified two pairs of predictive equations were derived using the same statistical methodology and using the same real data so as to thereby obtain comparative equations for testing the effect of using intensity normalised colour values.

Intra-site repeatability

In order to test the stability of the beef carcase system over the duration of a further yield trial in an operating abattoir a fake carcase having the size and shape of a real beef carcase and having its surfaces carefully coloured so as to closely match the fat and meat tissue colours of a real beef carcase was measured multiple times on a number of days during the period of the yield trials. Over a trial when the fake carcase was presented 37 times over a number of days, yield equations (1) and (3) exhibited only very small changes in the predicted yield - minimum - 0.062% and maximum +0.102% deviation from a median predicted yield. On the other hand, yield equations (2) and (4) displayed a drift of minimum -0.39% and maximum +0.16% from the median.

Likewise the RMS of the changes of the individual yield predictors for the intensity normalised yield equations (1) and (3) had a maximum of 0.048, compared to the RMS of the

changes in the individual intensity based predictor of equations (2) and (4) which had a maximum of about 0.3%.

These results show stability and repeatability of the system with the intensity normalised colour values showing substantially better intra-site repeatability.

In fact, during this intra-site test, one of the light bulbs of the carcase illumination system used during image capture failed in one carcase image capture and therefore significantly changed the carcase illumination conditions. The intensity normalised yield equations (1) and (3) showed only very small change in predicted yield and small change in the RMS of the changes for this trial with the failed light bulb, whereas the intensity dependent yield predictive equations (2) and (4) showed very large changes in predicted yield and RMS value for this trial with the failed light bulb. By chance, this demonstrated that the use of intensity normalised equations are robust to such changes in illumination conditions.

Inter-site repeatability

To investigate the repeatability of the system between two sites, the fake carcase was presented to the imaging system at multiple times at a different meat processing plant. Using the four yield equations above, the predicted yields for the fake carcase were compared to the results from the other processing plant. These results demonstrated that the intensity normalised colour values showed excellent inter-site repeatability and, in particular, the results were substantially more consistent than with the intensity dependent colour values.

Lighting sensitivity

To test the sensitivity of the system to lighting positioning during the capture of image data, the arrays of illuminating light sources used to illuminate the carcases were deliberately moved to different positions and images were captured at each of a number of different lighting positionings. Again the fake carcase was used to enable comparison of the results

from the various yield equations. This experiment caused changes in yield predictions of ±0.2% for yield equations (1) and (3) (the intensity normalised colour values) compared to changes in predicted yield from equations (2) and (4) of ±1.5%. Thus the use of the intensity normalised colour values shows robustness to lighting misalignment.

Animal type yield equations

After the completion of numerous yield trials, we determined that to achieve acceptable levels of yield prediction accuracy, multiple yield equations may need to be developed for different animal types, even when considering beef carcases alone. We derived equations based on both statistical methodologies and biological groupings. Six categories were finally selected. These are: Bulls, Cows, Light Grasslike, Heavy Grasslike, Light Grainlike, and Heavy Grainlike. "Light" and "Heavy" refer to carcase weight, and "Grasslike" and "Grainlike" refer to tissue colour. The six equations were derived using statistical methodologies as outlined earlier. The equations have a generally similar appearance to the yield equations given earlier but have different variables (depending on which dimensional data, colour patch values, etc. show the best correlations and predictive ability for yield for each of the six carcase categories) and also different co-efficients.

However, all six equations use intensity normalised colour values and show good yield predictive ability and inter-site and intra-site repeatability and illumination insensitivity. In use, each carcase is categorised into one of the six predetermined categories and the data captured is then used for the input to the respective equation for the relevant category to provide the yield prediction.

Yield Equation Labels

As mentioned, the BCS yield prediction accuracy relies upon application of the appropriate yield equation from one of the six categories mentioned above. The values for

the Wy and CompWy for a particular beef carcase side will therefore have been derived from the yield equations applicable to its category.

Wy = Predicted wholesale saleable meat yield

CompWy = Component predicted wholesale saleable meat yield for the BCS

Combined Equation Weightings

The BCS outputs not only its prediction of saleable meat yield, but also a yield that forms part of a combinatorial equation. This component yield (CompWy) is added to a weighted CAS predicted yield representing the currently selected carcase type. "CAS" refers to a "Chiller Assessment System" (available from Viascan Quality Assessment, of Beenleigh, Queensland, Australia) which provides measures relating to meat yield after further analyses later in the processing operation in a chiller. This weighted addition must be applied off-line at the end of the day. The formula that is implemented is as follows:

Combined Wy = BCS_CompWy + k' x CAS_Wy

where k' is defined according to which carcase type has been selected. The appropriate values are shown below in the table. Note that the CAS yield equations exist for only three carcase categories. These are: bull, cow, and table beef (where the table beef category includes all beef from the four subcategories of the BCS).

BCS Yield Category	k'	CAS Yield Category
Bull	0.4627	Bull
Cow	0.8095	Cow
Light grain	0.6057	Table beef
Heavy grass	0.8136	Table beef
Light grass	0.7751	Table beef
Heavy grain	1	Table beef

Table: CAS yield weightings by category

Conclusions

The use of colour normalised colour values in yield equations has been found to provide more accurate and therefore more reliable yield predictions of beef carcases than measured colour values which are influenced by light intensity at the time and place of the image capture even if considerable measures have been taken to calibrate the equipment to remove equipment, site and time induced variables and even if considerable measures have been taken to provide controlled lighting conditions at the image capture station.

The invention has been mostly described herein and illustrated in connection with predicting yield of a meat carcase, i.e. the amount of saleable meat, particularly a beef carcase. "Yield" is the primary measure used for carcase grading in Australia where the invention has been developed. However, in other countries or regions, there can be different parameters used to grade meat such as meat carcases.

For example, in Europe there is a scoring or grading system known as "EUROP" which involves determining one grading measure for the shape or "conformation" of a carcase (which categorises the degree of fatness or fullness of the carcase) and a "fat score" (which provides a score or grading for the overall fat coverage of the carcase). The present invention is equally applicable to the process of calculating the conformation and fat scores in the EUROP system for a meat portion or carcase using light intensity independent colour measures in appropriate predictive equations. It will be appreciated that the capture of colour data for a carcase (together with other data such as dimensional data), can be used in an analogous manner to that described above for developing a yield predictive equation to develop equations to provide EUROP conformation and fat score measures. The use of light intensity independent measures of colour values in such conformation and fat score predictive

equations will improve the intra-site and inter-site repeatability of the system and light orientation insensitivity as established for the yield predictive equations.

In the United States, there is a further meat grading system developed by the USDA. This USDA grading system is based on analysis of the rib eye muscle colour and size and on the fat weight. The system involves the allocation of two grading measures known as the "yield grade" and the "quality grade". As with the EUROP grading system, the present invention using light intensity independent measures of colour values can be used in predictive equations for the "yield grade" and "quality grade" under the USDA grading system by developing such equations using multiple regression analysis techniques or other statistical methologies. The use of light intensity independent colour values in such equations for the USDA grading system will have the same advantages as described above for the Australian yield equations.

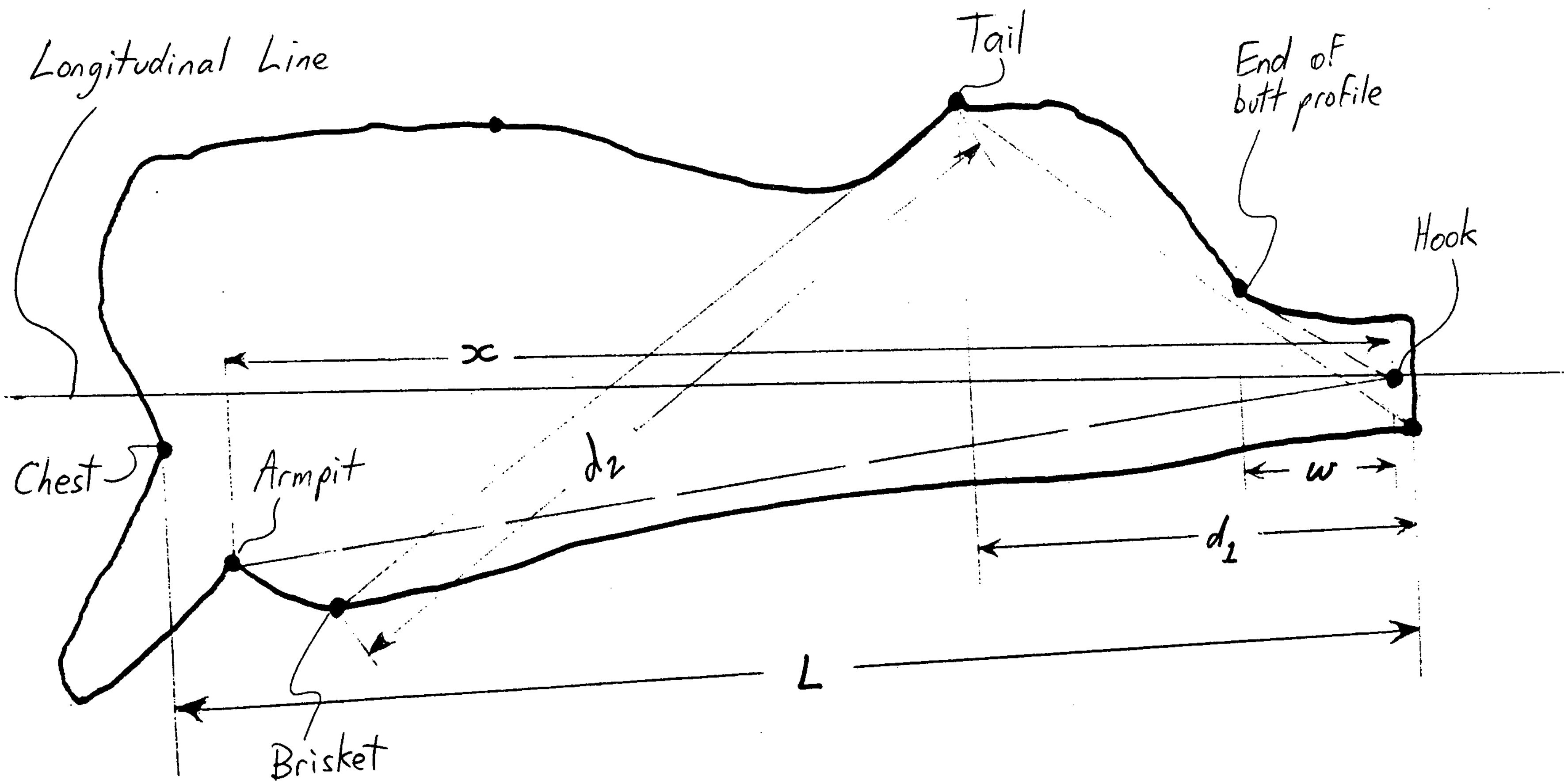
It is to be understood that various alterations, modifications and/or additions may be made to the features of the possible and preferred embodiment(s) of the invention as herein described without departing from the spirit and scope of the invention.

Dated this 27th day of August 1999

PATENT ATTORNEY SERVICES

Attorneys for

MEAT & LIVESTOCK AUSTRALIA LIMITED



Longitudinal Line
Tail
End of butt profile
Hook
Chest
Armpit
Brisket
x
d_2
w
d_1
L